Setting up tracking tools for NuFact bowtie decay ring studies

D. Kelliher, F. Lemuet, F. Méot, G. Rees

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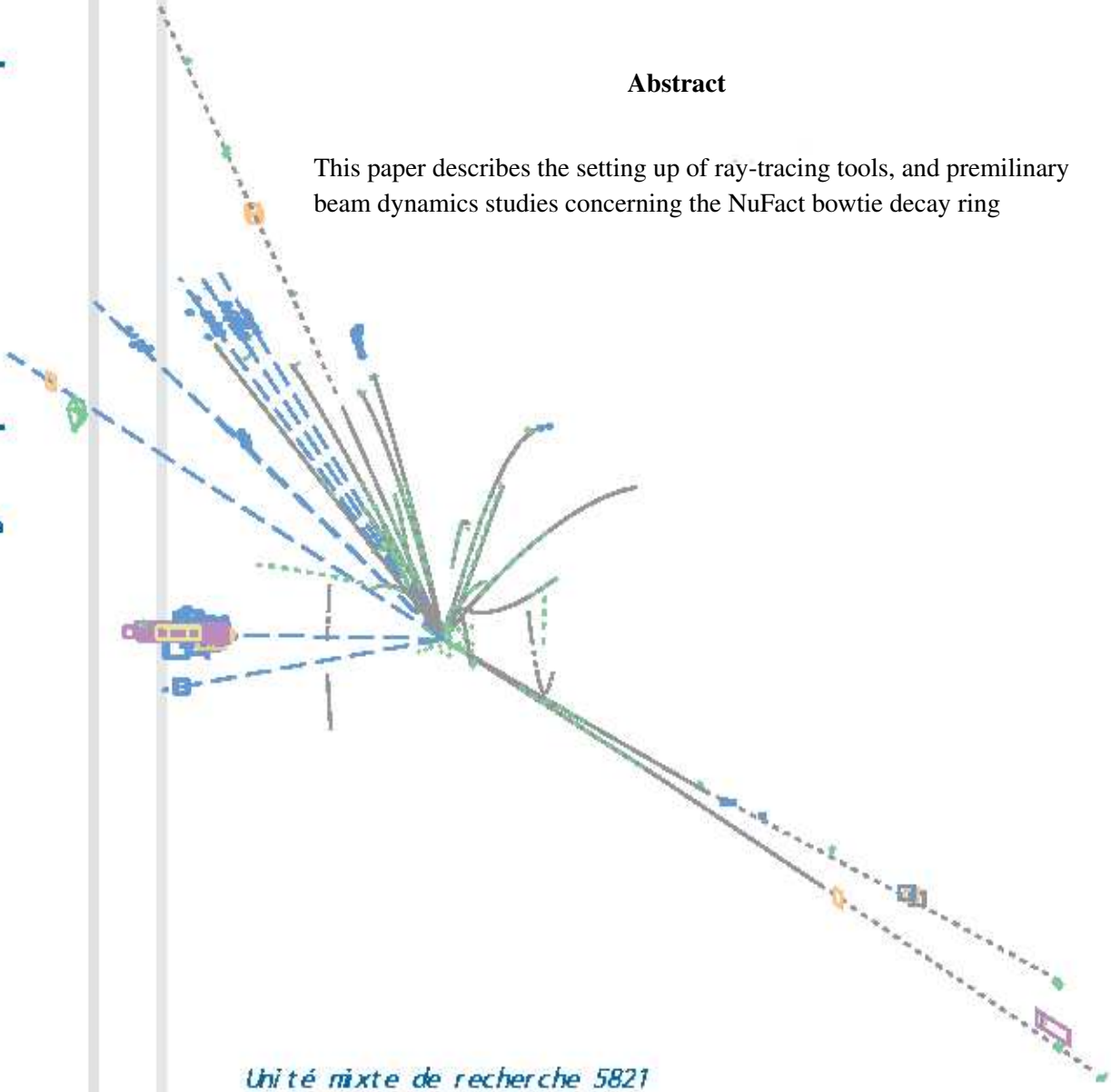
Abstract

This paper describes the setting up of ray-tracing tools, and premilinary beam dynamics studies concerning the NuFact bowtie decay ring



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Contents

1 Introduction

The muon storage ring in the neutrino factory (NuFact in the following) is located at the high energy end of the muon acceleration chain. It delivers the μ^+/μ^- decay neutrinos to physics detectors [1].

The design of concern here is a 20 GeV (upgradable to 50 GeV) bowtie geometry [2] (Fig. 1) which features two decay straight sections, each one aiming at a distant detector, and two return straight sections

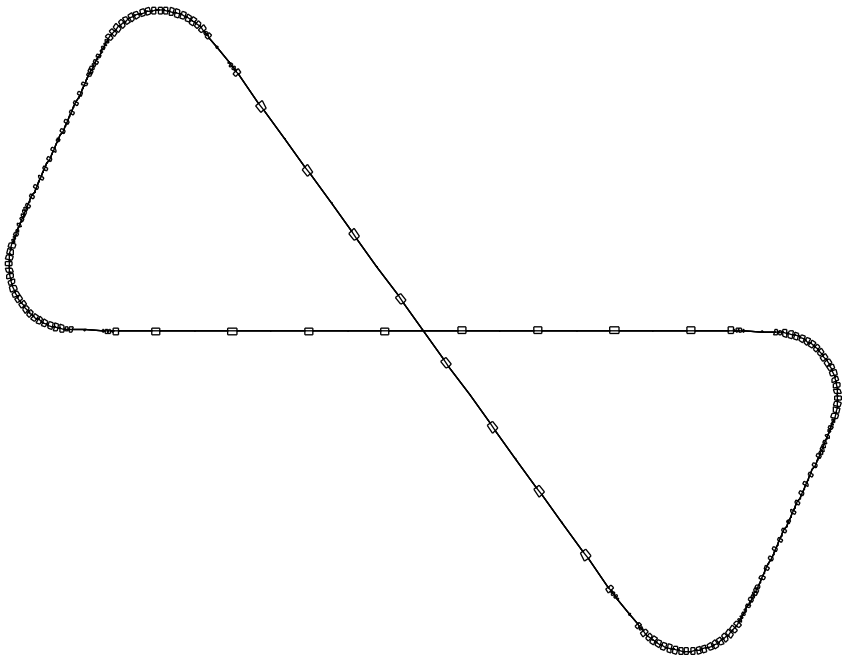

Figure 1: Bowtie decay ring. The two Tuning/Collimation/RF straights are on the left and on the right. The 8-solenoid decay straights are the two others. The four, ten cells arcs are identical.

devoted to tunning, collimation, RF. Geometry and optical parameters are given in Tab. 1 and general behavior is shown in Figs. 2 ; Tab. 1 also dispalys MAD outputs as obtained from prior translation from the RAL STRING code that has been used for the design, for further checks and comparisons with ray-tracing data. More details can be found in Ref. [3].

Much of this design is derived from the earlier studied isoceles triangle decay ring [4, 3, 5]. A particularity is in its being based on solenoid focusing decay straights, which has the virtue of minimizing the betatron amplitudes, compared to equivalent quadrupole focusing. The solenoidal focusing ensures the requested ratio, for the r.m.s. divergences of the 20 GeV muon and the neutrino beam, of 0.1 for an assumed muon normalized r.m.s. emittance of 4800 π mm mr (3 π cm, total).

It is planned to use the ray-racing code Zgoubi for machine design and spin dynamics studies [6], (this is for the sake of accuracy in the representation of magnetic fields - combined function dipoles, solenoids, fringe fields, etc., given the very large beam emittances of concern) thus the goal of the present work is to show how the optics data files have been set up, and to give preliminary results concerning beam and spin dynamics, that show the correct behavior of these, thus allowing further prospects.

Table 1 : Muon storage ring parameters [2].

		Matrix
Energy	(GeV)	20
Circumference	(m)	1608.8
Requested transverse admittance	(π cm, norm.)	6
Requested $\delta p/p$ admittance	(%)	± 1
Total tunes ν_x/ν_z		14.3749 / 12.7882
Total chromaticities ξ_x/ξ_z		-17.7 / -17.7
Phase adavnces, H/V :	(2π)	
Arc cell		0.2 / 0.2
production straight		0.69963 / 0.69963
sol./arc match section		0.252525 / 0.205128
tuning straight		1.98279 / 1.284238

Matching conditions :	β_x	α_x	β_x	α_z	D_x	D'_x
collimation st centre	8.86984	0	21.08630	0	0	0
arc input/output	3.78758	0	12.67568	0	0.837046	0
production st waists	94.21980	0	94.21980	0	0	0

MAD [7] outputs :

```
--------------------------------------------------------------------------------------------------------------------------------------------
     ELEMENT SEQUENCE       I              H O R I Z O N T A L              I               V E R T I C A L
 pos.  element occ.     dist I   betax  alfax   mux    x(co)  px(co) Dx    Dpx  I   betay  alfay   muy    y(co)  py(co) Dy    Dpy
 no.   name    no.      [m]  I   [m]    [1]     [2pi]  [mm]   [.001] [m]   [1]  I   [m]    [1]     [2pi]  [mm]   [.001] [m]   [1]
--------------------------------------------------------------------------------------------------------------------------------------------
ARC TO SOLENOID STRAIGHT MATCHING SECTION :
--------------------------------------------------------------------------------------------------------------------------------------------
 begin MATCHSEC   1     0.000    3.788  0.000   0.000  0.0000  0.000  0.000 0.000   12.624  0.000   0.000  0.0000  0.000  0.000 0.000
 end   MATCHSEC   1    35.000   94.221 -0.001   0.253  0.0000  0.000  0.065 0.043   94.584 -0.014   0.205  0.0000  0.000  0.000 0.000
--------------------------------------------------------------------------------------------------------------------------------------------
 total length =          35.000000          mux          =          0.252529          muy          =          0.205420
 delta(s)     =           0.000000 mm       dmux         =         -0.052988          dmuy         =         -0.067694
--------------------------------------------------------------------------------------------------------------------------------------------
ARC CELL :
--------------------------------------------------------------------------------------------------------------------------------------------
 begin ARCCELL    1     0.000    5.576 -1.348   0.000  0.0000  0.000  0.994 0.222    9.539  1.955   0.000  0.0000  0.000  0.000 0.000
 end   ARCCELL    1     8.200    5.576 -1.348   0.200  0.0000  0.000  0.994 0.222    9.539  1.955   0.200  0.0000  0.000  0.000 0.000
--------------------------------------------------------------------------------------------------------------------------------------------
 total length =           8.200000          Qx           =          0.200000          Qy           =          0.200000
 delta(s)     =           0.000000 mm       Qx'          =         -0.194459          Qy'          =         -0.222650
--------------------------------------------------------------------------------------------------------------------------------------------
10 CELL ARC :
--------------------------------------------------------------------------------------------------------------------------------------------
 begin ARC10      1     0.000    3.788  0.000   0.000  0.0000  0.000  0.000 0.000   12.624  0.000   0.000  0.0000  0.000  0.000 0.000
 end   ARC10      1    82.000    3.788  0.000   2.000  0.0000  0.000  0.000 0.000   12.624 -0.004   2.000  0.0000  0.000  0.000 0.000
--------------------------------------------------------------------------------------------------------------------------------------------
 total length =          82.000000          mux          =          2.000000          muy          =          2.000000
 delta(s)     =           0.000000 mm       dmux         =         -1.944237          dmuy         =         -2.236326
--------------------------------------------------------------------------------------------------------------------------------------------
TUNING SECTION :
--------------------------------------------------------------------------------------------------------------------------------------------
 begin TUNINGSE   1     0.000    3.788  0.000   0.000  0.0000  0.000  0.000 0.000   12.624  0.000   0.000  0.0000  0.000  0.000 0.000
 end   TUNINGSE   1   145.246    3.788  0.000   1.983  0.0000  0.000  0.005-0.024   12.624  0.000   1.285  0.0000  0.000  0.000 0.000
--------------------------------------------------------------------------------------------------------------------------------------------
 total length =         145.245748          mux          =          1.982785          muy          =          1.285053
 delta(s)     =           0.000000 mm       dmux         =         -4.349365          dmuy         =         -3.028322
--------------------------------------------------------------------------------------------------------------------------------------------
SOLENOID STRAIGHT :
--------------------------------------------------------------------------------------------------------------------------------------------
 begin SOLESTRA   1     0.000   94.000  0.000   0.000  0.0000  0.000  0.000 0.000   94.000  0.000   0.000  0.0000  0.000  0.000 0.000
 end   SOLESTRA   1   425.156   93.698 -0.057   0.700  0.0000  0.000  0.000 0.000   93.698 -0.057   0.700  0.0000  0.000  0.000 0.000
--------------------------------------------------------------------------------------------------------------------------------------------
 total length =         425.155626          mux          =          0.699752          muy          =          0.699752
 delta(s)     =           0.000000 mm       dmux         =         -0.714953          dmuy         =         -0.714953
--------------------------------------------------------------------------------------------------------------------------------------------
FULL BOWTIE :
--------------------------------------------------------------------------------------------------------------------------------------------
 begin BOWTIE     1     0.000  114.889 -0.329   0.000  0.0000  0.000  0.000 0.000   98.535  0.033   0.000  0.0000  0.000  0.000 0.000
 end   BOWTIE     1  1608.803  119.269 -0.301  14.400  0.0000  0.000  0.000 0.000   97.094 -0.086  12.751  0.0000  0.000  0.000 0.000
--------------------------------------------------------------------------------------------------------------------------------------------
 total length =        1608.802747          Qx           =         14.399904          Qy           =         12.751446
 delta(s)     =           0.000000 mm       Qx'          =        -17.691073          Qy'          =        -17.663926
 alfa         =           0.540925E-02      betax(max)   =        136.836657          betay(max)   =        130.757453
 gamma(tr)    =          13.596636          Dx(max)      =          1.290411          Dy(max)      =          0.001194
--------------------------------------------------------------------------------------------------------------------------------------------
```

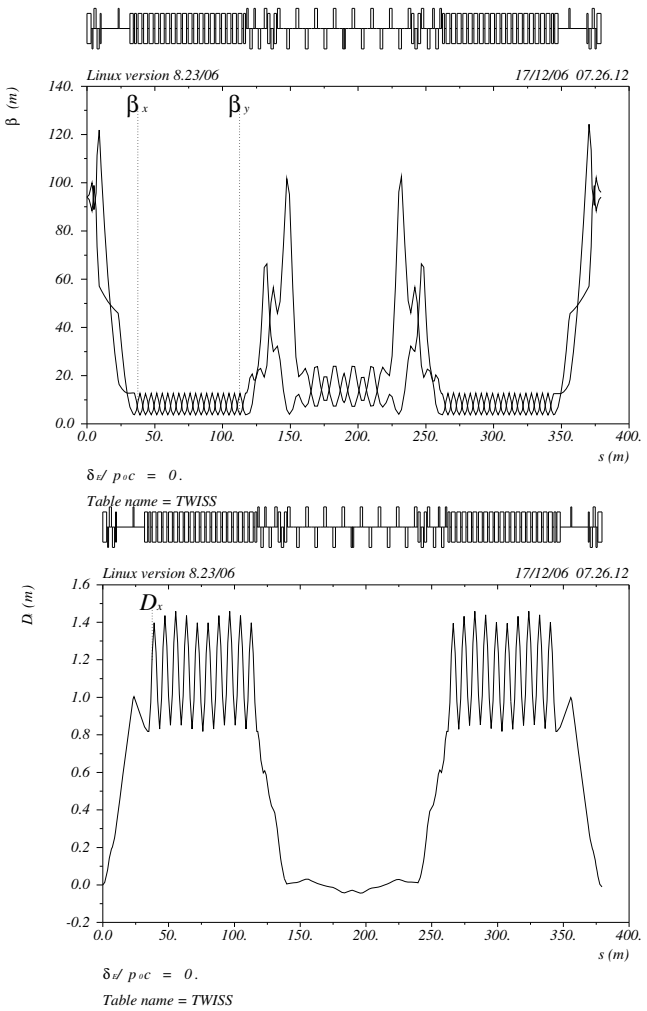

Figure 2: Optical functions in half the bowtie ring.

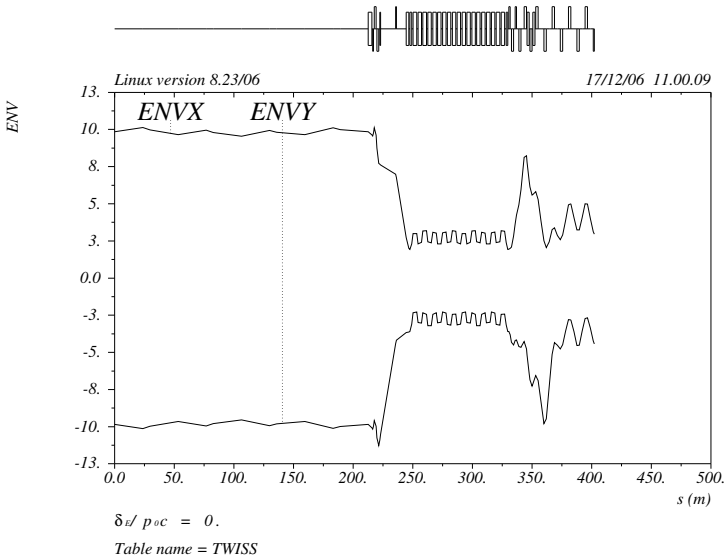

Figure 3: Beam envelopes ($\epsilon_{x,z} = 1$) in a quarter of the bowtie, from middle of production straight to middle of tuning section.

2 Ray-tracing sample results

The essential of Zgoubi data file is given in App. 3. The subparts of the bowtie ring are very near, in geometry and optical tunings, to the triangle ones, therefore it can usefully referred to Ref. [3] for more details.
The Zgoubi optics file is obtained by direct translation from a MAD "survey" output. The agreement between transport type and ray-tracing outputs is straightforward as long as pure dipoles and other higher order multipoles are concerned, which is not the case her : the use of combined function dipoles in the arcs, in addition to the presence of fringe fields, requires positionning adjustments ; the superimposition of a sextupole component for chromaticity correction requires additional adjustment of both closed orbit and tuning, minor though ; the long fall-offs of solenoid fields requires strength adjustment.
Zeroing of the horizontal closed orbit is a first effect of dipole positionning adjustment. A first approach is showned in Fig. 4, it can still be improved by better adjustment of all dipoles.
Beam envelopes obtained using STRING's strengths are shown in Fig. 5, they are in excellent agreement with transport methods (Fig. 3), which shows that little gradient adjustments will be needed to get identical ray-tracing focusing conditions.

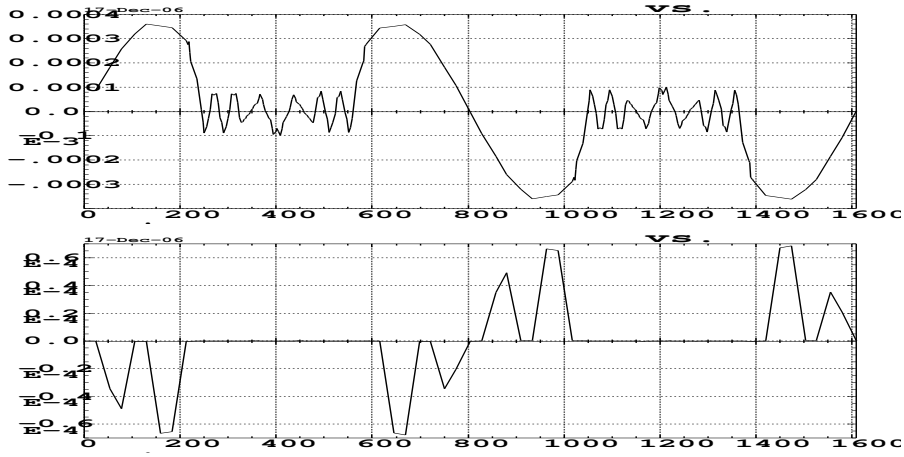

Figure 4: Residual geometrical closed orbits. The (negligile) vertical one is due to residual coupling in the silenoid.

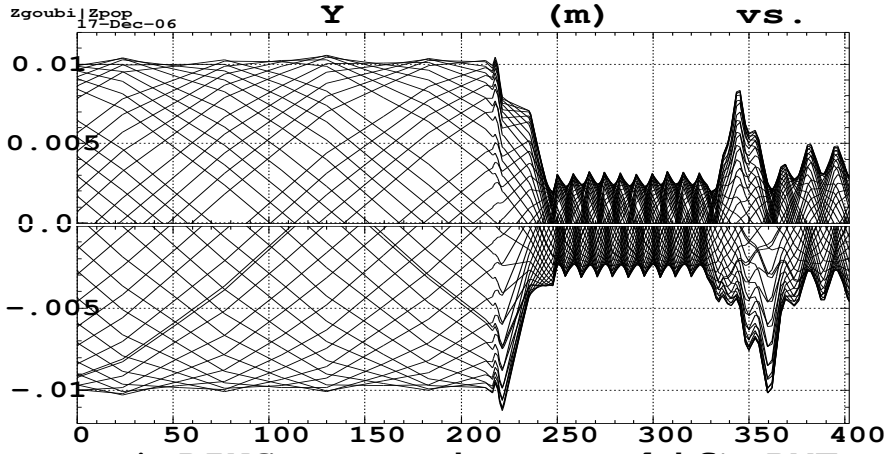

Figure 5: Horizontal (top) and vertical (bottom) beam envelopes ($\epsilon_{x,z} = 1$) in the bowtie ring, from ray-tracing.

Focusing properties computed from ray-tracing are the following :

Middle of tuning straight :

```
Beam  matrix  (beta/-alpha/-alpha/gamma) and  periodic  dispersion  (MKSA units)
    7.59592   -0.228524       0.00000       0.00000      0.00000    -3.021585E-02
  -0.228524    9.025691E-02   0.00000       0.00000      0.00000    -4.713025E-04
    0.00000     0.00000       21.9151     -4.881490E-02  0.00000      0.00000
    0.00000     0.00000     -4.8815E-02    2.900786E-02  0.00000      0.00000
```

Arc input/output :

```
     3.78813     1.142890E-04  0.00000      0.00000      0.00000     0.818142
 1.142890E-04 0.263982      0.00000      0.00000      0.00000    -3.255178E-05
    0.00000      0.00000      12.6777     1.386475E-03  0.00000      0.00000
    0.00000      0.00000    1.386475E-03 7.887899E-02  0.00000      0.00000
```

Middle of the production section :

```
Beam  matrix  (beta/-alpha/-alpha/gamma) and  periodic  dispersion  (MKSA units)

   80.893747    -0.176882     0.000000     0.000000     0.000000    -0.018887
   -0.176882     0.012749     0.000000     0.000000     0.000000    -0.000278
    0.000000     0.000000    94.896068    -0.109185     0.000000     0.000003
    0.000000     0.000000    -0.109185     0.010663     0.000000     0.000000

                          Betatron  tunes (fractional) :
                 NU_Y = 0.34725094         NU_Z = 0.76608261

                          Chromaticities :
           dNu_y / dp/p = -14.393117        dNu_z / dp/p = -16.228313
```

Comparison with data in Tab. 1 shows satisfactory agreement in optical functions at the various observation points ; this can be improved by adjusting the quadrupoles (in the matching and tuning sections) whereas no attempt has been done on that. The difference in fractional part of tunes with design values (Tab. 1) is very small (0.027 horizontal and 0.022 vertical) although the sole arc cells have been tuned to their exact requested phase advance, 0.2. This small difference can easily be zeroed by adjustment of the tuning section quadrupoles. Chromaticities as well are in good agreement.

Large amplitude tracking samples below have the mere goal of giving a rapid idea of expectable admittance. They are clearly satisfactory and justify further inspection, including 4-D motion, beam transmission, etc., as performed in the triangle ring case [3].

Horizontal motion **Vertical motion**

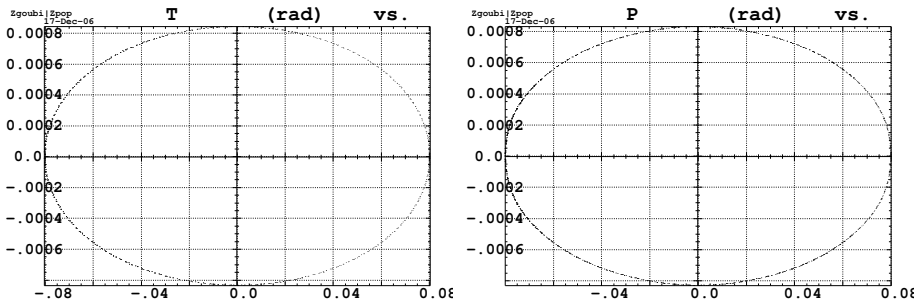

Figure 6: Phase space trajectories of an on-momentum particle launched on $\epsilon_x/\pi \approx 1.5$ cm (left) or $\epsilon_z/\pi \approx 1.5$ cm (right) invariant. 1000 turns in the ring.

3 Spin tracking

The preliminary data installations and tests above show a good behavior of particle dynamics computation, allowing further spin dynamics studies using ray-tracing method. Static mode can be considered (search for spin closed orbit, resonance strength computation, etc., the beam staying at constant distance from the resonance, see methods in Ref. [6] for instance), as well as resonance crossing mode if using "CAVITE" for acceleration (although no acceleration is going to occur in reality) which would for instance yield precise estimate of the resonant energy, or as well stationary bucket mode (see example in Section 3 of Zgoubi users' guide [8]).

Preliminary checks show a good symplecticity of the spin tracking using the integration steps given in App. 3. This should be checked further, depending on transverse amplitudes in particular. The spin generator in Zgoubi allows creating all sort of initial conditions, random or not, whereas the analysis/graphic interface software zpop [8] allows all sorts of spin analysis, spin motion plots.

The Figure below shows for illustration a 1000-turn tracking in the defect-free bowtie with tunig conditions addressed above (in particular, no vertical closed orbit defect).

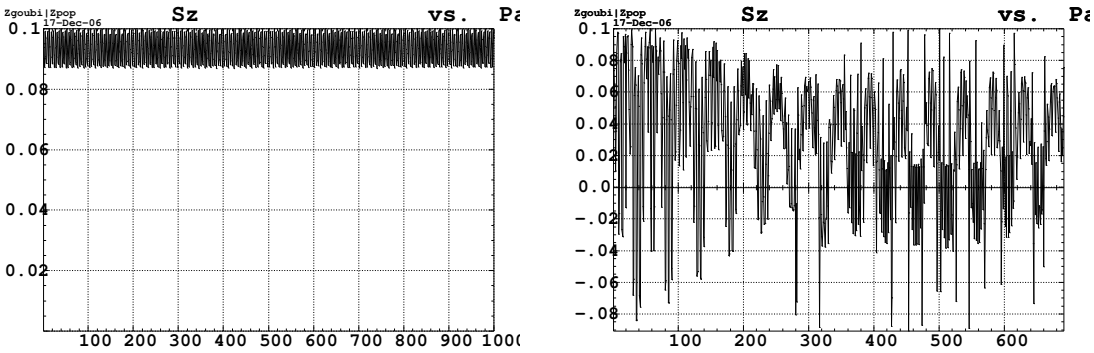

Figure 7: Vertical component of the spin, versus turn number, observed in the middle of the production straight. Left : $\epsilon_x/\pi \approx 1.5$ cm, $\epsilon_z/\pi = 0$, right : $\epsilon_x/\pi \approx 0$ cm, $\epsilon_z/\pi \approx 1.5$ cm.

On the other hand, it has been checked that all along the tracking range, $S_x^2 + S_y^2 + S_z^2 = 1$, at computer precision, which is an indication of good symplecticity, and of small enough integration step size.

Appendix

Zgoubi data

Object definition and storage options :

```
'OBJET'
       67064.301000
6
.001 .001 .001 .001 0. .000001
0. 0. 0. 0. 0. 1.
'PARTICUL'
105.66  1.60217733D-19  1. 0. 0.
'SPNTRK'
    3
'SPNPRNL'
zgoubi.spn
  'SPNPRT'
'PICKUPS'
1
DRIF
'FAISTORE'
b_zgoubi.fai DRIF #S #E
 1
```

"PARTICUL" allows input of the muon mass and charge for γ computation, and of the gyromagnetic factor, two quantities necessary for spin tracking.

"PICKUPS" is used for computation of closed orbit.

"FAISTORE" allows storage of particle coordinates for phase-space plots.

"SPNTRK" requests spin tracking while the option 3 sets all initial spins upright, whereas "SPNPRNL" causes storage of spin components.

Solenoid cell :

```
'DRIFT'    DRIF      D1
   2360.0000
'SOLENOID' SOLE      SOLP
0  .soleno
  594.4453      20.      42.17
    600.   600.
1.  Soleno  SOLP
1 0. 0. 0.
'DRIFT'    DRIF      D1
   2360.0000
```

Solenoid to arc matching section :

```
'CHANGREF'
  0.     0.    -1.111652714
'CHANGREF'
  0.     0.96109104     0.0
'MULTIPOL' SBEN      BMS
0  .Dip
 299.9812  10.00   8.67454379   0.33532151   0. 0. 0. 0. 0. 0. 0. 0. 0.
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #120|300|120    Dip  BMS
 2  0.  0.  0.
'CHANGREF'
  0.    -0.96109104     0.0
'CHANGREF'
  0.     0.    -1.111652714
'DRIFT'    DRIF      D2
     60.0000
'MULTIPOL' QUAD      QD1
0  .Quad
   80.0000 10.00    0.00   -6.5863675 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|80|30    Quad  QD1
1 0. 0. 0.
'DRIFT'    DRIF      D2
     60.0000
'MULTIPOL' QUAD      QF1
0  .Quad
  160.0000 10.00    0.00    7.7113265 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|160|30    Quad  QF1
1 0. 0. 0.
'DRIFT'    DRIF      D3
     70.0000
'MULTIPOL' QUAD      QD2
0  .Quad
  160.0000 10.00    0.00   -6.0648503 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|160|30    Quad  QD2
1 0. 0. 0.
'DRIFT'    DRIF      D4
     70.0000
'CHANGREF'
  0.     0.    -0.190643112
'CHANGREF'
  0.    3.54677553E-02     0.0
'MULTIPOL' SBEN      BMB
0  .Dip
  79.9999  10.00   5.57866005   0.   0. 0. 0. 0. 0. 0. 0. 0.0
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #120|80|120    Dip  BMB
 2  0.  0.  0.
'CHANGREF'
  0.    -3.54677553E-02     0.0
'CHANGREF'
  0.     0.    -0.190643112
'DRIFT'    DRIF      D5
   1250.0000
'MULTIPOL' QUAD      QF2
0  .Quad
   80.0000 10.00    0.00    6.1619058 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|80|30    Quad  QF2
1 0. 0. 0.
'DRIFT'    DRIF      D6
    800.0000
'CHANGREF'
  0.     0.     0.078982232
'CHANGREF'
  0.    -5.48572737E-02     0.0
'MULTIPOL' SBEN      BMR
0  .Dip
 239.9999  10.00  -0.77040116  -0.77762050   0. 0. 0. 0. 0. 0. 0. 0.0
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #120|240|120    Dip  BMR
 2  0.  0.  0.
'CHANGREF'
  0.     5.48572737E-02     0.0
'CHANGREF'
  0.     0.     0.078982232
'DRIFT'    DRIF      D7
     90.0000
```

Arc cell :

```
'DRIFT'    DRIF      D8
    120.0000
```

```
'CHANGREF'
  0.     0.    -2.750000033
'CHANGREF'
  0.     2.3573085     0.0
'MULTIPOL' SBEN      BFA
0  .Dip
 289.8887  10.00  22.19900284   9.0893658   0.58233992e-20 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #120|290|120    Dip  BFA
 2  0.  0.  0.
'CHANGREF'
  0.    -2.3573085     0.0
'CHANGREF'
  0.     0.    -2.750000033
'DRIFT'    DRIF      D8
    120.0000
'CHANGREF'
  0.     0.    -2.750000033
'CHANGREF'
  0.     2.2776455     0.0
'MULTIPOL' SBEN      BDA
0  .Dip
 289.8887  10.00  22.19900284  -9.0582687  -0.91139609e-20 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #120|290|120    Dip  BDA
 2  0.  0.  0.
'CHANGREF'
  0.    -2.2776455     0.0
'CHANGREF'
  0.     0.    -2.750000033
```

Tuning section, up to first DS dipole :

```
'DRIFT'    DRIF      D9
     80.0000
'MULTIPOL' QUAD      QF3
0  .Quad
  110.0000 10.00    0.00    6.6368978327 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|110|30    Quad  QF3
1 0. 0. 0.
'DRIFT'    DRIF      D10
    120.0000
'MULTIPOL' QUAD      QD3
0  .Quad
  180.0000 10.00    0.00   -5.8842217697 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|180|30    Quad  QD3
1 0. 0. 0.
'DRIFT'    DRIF      D10
    120.0000
'MULTIPOL' QUAD      QF4
0  .Quad
  110.0000 10.00    0.00    6.1766221221 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|110|30    Quad  QF4
1 0. 0. 0.
'DRIFT'    DRIF      D11
    210.0000
'MULTIPOL' QUAD      QD4
0  .Quad
  180.0000 10.00    0.00   -3.1251964266 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|180|30    Quad  QD4
1 0. 0. 0.
'DRIFT'    DRIF      D7
     90.0000
'DRIFT'    DRIF      D7
     90.0000
'MULTIPOL' QUAD      QF5
0  .Quad
  180.0000 10.00    0.00    6.7277297220 0. 0. 0. 0. 0. 0. 0. 0.0
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
9.0 9.0  1.00 0.00 0.00 0.00 0.00 0. 0. 0. 0.
6  .1122 6.2671 -1.4982 3.5882 -2.1209 1.723  arc
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #30|180|30    Quad  QF5
1 0. 0. 0.
'DRIFT'    DRIF      D12
     60.0000
'CHANGREF'
  0.     0.    -0.974019657
'CHANGREF'
  0.     0.764974827E-30     0.0
'MULTIPOL' SBEN      BMT
0  .Dip
 179.9913  10.00  12.66758953   0.   0. 0. 0. 0. 0. 0. 0. 0. 0.0
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
20.00 11.20  1.00 1.00 1.00 1.00 0.00 0. 0. 0. 0.
6 .015527 3.874961 -2.362230 2.978209 12.604429 15.025689
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 #120|180|120    Dip  BMT
 2  0.  0.  0.
'CHANGREF'
  0.    -0.764974827E-30     0.0
'CHANGREF'
  0.     0.    -0.974019657
```

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